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Potential of bioethanol production from agricultural wastes in Iran

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ABSTRACT

The production of bioethanol from agricultural residues such as wheat, barley, sugar cane, corn and rice in Iran is investigated in this paper. In Iran, agricultural residues are not commonly used for energy application. This paper aims to cover several perspectives on the size of the bioethanol feedstock resource in Iran. Crop residues and sugar cane bagasse are included in feedstock for production of bioethanol. There are approximately 17.86 MT of wasted crops in Iran that can potentially produce 4.91 GL of bioethanol per year. Wheat, sugar cane bagasse, rice, barely and corn are the most favourable bioethanol production source in Iran. Agricultural waste materials can be used for production of bioethanol fuel. Bioethanol can be considered as the optimum alternative fuel for gasoline. Bioethanol is an environmentally friendly fuel and has the potential to provide comparable engine performance results.

Contents

1. Introduction

Iran is one of the top countries that have many natural resources such as crude oil and metals. However, the utilization of these natural resources is limited. A third of Iran's total land area can be utilized to produce crops if sufficient water is provided. However, there is only 12% of the total land area is utilized for crop growing. The total production of wheat, corn, rice and barley has rapidly increased in the previous decade. This increase is attributed to a combination of higher yields and seeded area. In the year of 2007 and 2008, the total production of field crops is forecast at a record of 22.0 MT, marginally higher than 2006–2007. Total

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domestic use is also forecast to increase marginally to a record of 26.9 MT [1]. The rate of agricultural wastes in Iran is recently increased, this rise required a good agricultural waste management. Waste management extension deals with rising the efficiency and productivity of the agricultural industry, intellectually and/or economically. With managing the residual of agriculture, energy production from these materials will have high share of energy supply in Iran, and consequently there is a need for more research and development on renewable energies. Energy utilization in Iran is growing rapidly and it become very important to use a non-fossil energy sources as there is a large, unutilized energy potential in agricultural waste fraction. Fig. 1 shows Iran's energy consumption by resources in 2005 and 2006. Iran policy towards fossil fuels consumption for energy supply seems to be continued. However, in renewable energy resources Iran policy is to supply 1% of electricity with renewable resources up to 2010 [2]. Currently, renewable energy resources in Iran are not efficiently utilized. Fig. 1 shows that biomass and biofuels are not effectively used to meet a variety of energy needs, including fuelling vehicles, generation electricity, etc.

Considering, the availability of all types of biomass resources in Iran, Power Ministry conducted a research to evaluate the potential of using biomass as a source of renewable energy. The biomass components that reported are as follows:

1. Animal waste.
2. Urban waste.
3. Biogas from urban waste water.
4. Methane from industrial waste water.
5. Agricultural and wood wastes.

With the high rate of agricultural wastes in Iran, government needs to manage these materials considerably. One of the optimum examples is producing biofuels from crop residuals. The advantages of using biofuels as an alternative fuel is (1) reducing the greenhouse gas emissions, (2) reducing the fossil fuel use, (3) increasing national energy security, (4) increasing rural development, and (5) sustainable fuel supply for the future. The energy obtained from ethanol is relatively high, this makes it extremely attractive in comparison to other renewable sources [3]. A biofuel industry is growing in many developing countries. Many developing countries have extensive biomass resources that are becoming more valuable as the demand for biomass and biofuels increases. The approaches to biofuel development in different parts of the world are varied. This paper aims to demonstrate an overview of the potential of bioethanol production from agricultural wastes in Iran.

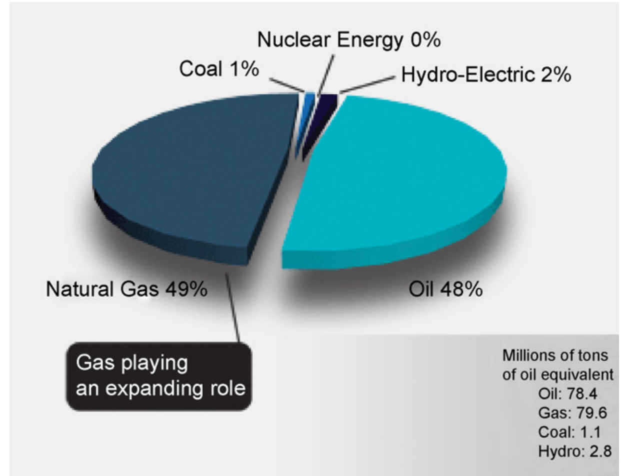


Fig. 1. Iran's 2005–2006 energy consumption [2].

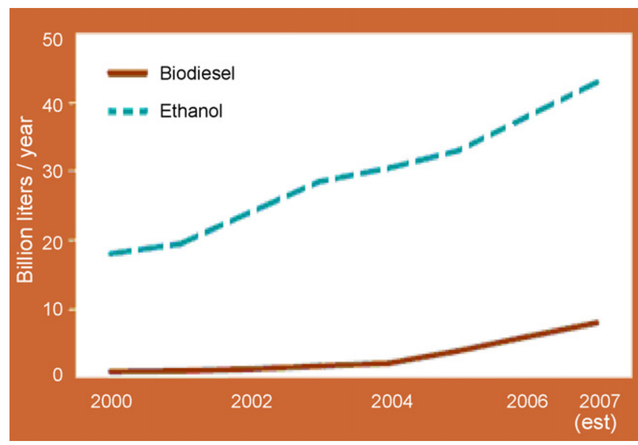


Fig. 2. World biofuel production [5].

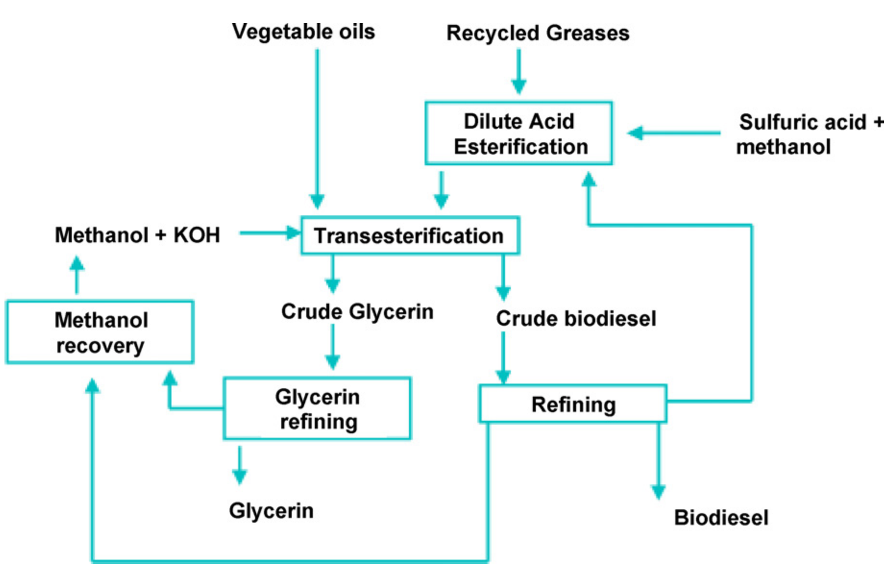


Fig. 3. Basic technology and main steps for production of biodiesel.

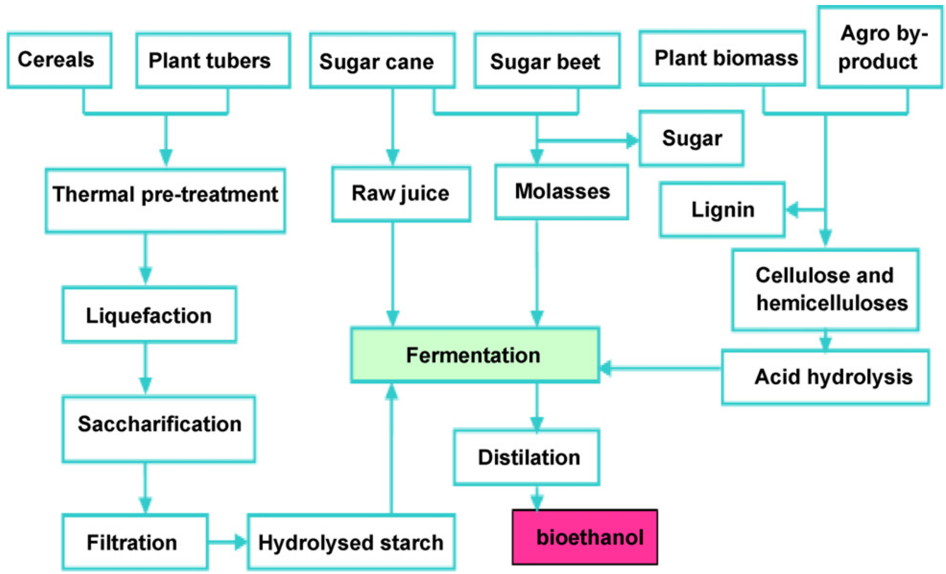


Fig. 4. Basic technology and main steps for production of bioethanol [8].

2. Importance of biofuel energy

Biofuels is an alternative fuel for gasoline and diesel fuel that are receiving great attention worldwide. Biofuels considers one of the optimum alternative fuel for SI and CI engines because it is a renewable and environmentally friendly fuel. Biofuel can be used either pure or in blends form with gasoline and diesel in the IC engines. Biofuel can be easily produced from common feedstock and agricultural wastes. Other source of alternative fuels include biodiesel is typically produced from either animal or vegetable oils and alcohol-based fuels like ethanol, which produced from the fermentation of sugar cane or corn. This techniques is widely used in the United States of America. In other countries such as Brazil, ethanol became one of the common fuels used that available in the fuel stations in this country. Ethanol produced from biomass considers one of the modern forms of biomass energy that has the potential to be a sustainable transportation fuel for gasoline engines [4]. Production of biofuels is booming as oil prices continue rising which makes it more profitable business.

In 2007, the annual world total production of bioethanol is estimated to be 45 billion litres, while the annual production of biodiesel is approximately 5 billion litres [5]. The total world production of biofuel from 2000 till 2007 is presented in Fig. 2. It can be clearly seen that the ethanol and biodiesel are rapidly increased after the year of 2004. Figs. 3 and 4 illustrate that the process stages of biodiesel and bioethanol production, respectively.

3. Importance of biofuel energy for Iran

Primary energy demand in Iran is projected to increase at an average annual rate of 2.6% in 2003–2030, down from around 5% over the past decade. This assumes that the progressive removal of energy subsidies, now equivalent to a staggering 10% of GDP (Gross Domestic Product). Iran's oil reserves are the second largest in the Middle East, after Saudi Arabia. Oil production is projected to grow from 4.1 mb/d (million barrels per day) in 2004 to 4.5 mb/d in 2010 and to 6.8 mb/d in 2030. Iran holds the second largest natural gas reserves in the world. Gas production which is expected to grow to 110 bcm (billion cubic meters) in 2010 and to 240 bcm in 2030. Electricity generation is estimated to be increased from 153 TWh (Terra Watt hour) in 2003 to 359 TWh in 2030, requiring 54 GW of new generating capacity and total investment in power infrastructure of $92 billion [6]. Fig. 5 shows that renewable energy resources do not have wide applications in Iran at present and even in 2030, while the fossil fuels consumption will increase. The use of renewable energy, especially biofuels will make Iran stand for a better chance to have share of energy from non-fossil energy sources, and it will sure decrease the fossil fuel consumption. In Iran, biofuel has great potential to improve energy services based on agricultural residues.

Biofuel can blend as fuel with gasoline or diesel fuel in order to be used for IC engine. Various agricultural residues such as wheat straw, rice straw and husk, corn stalk and cob, barely straw and sugar cane bagasse are produced and disposed. The available agricultural residues in Iran have been estimated to be 17–20% of total production of crops [13]. The use of agricultural waste is already exists in some industries in Iran but it is on limited small scale. The availability of agricultural waste for bioethanol production and various options in Iran is strongly recommended by the authors. The government has just started producing biofuel from residual materials. The data for biomass and corps residual for

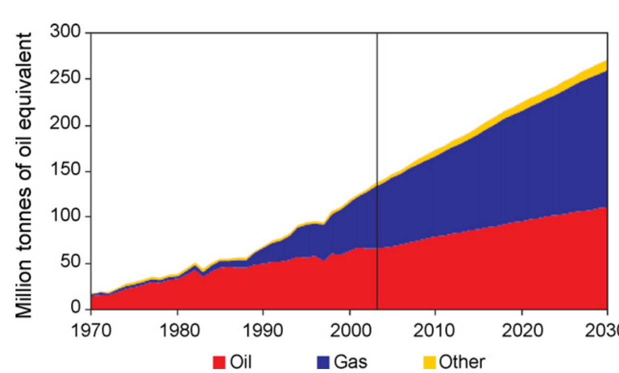


Fig. 5. Iran primary energy demand [2].

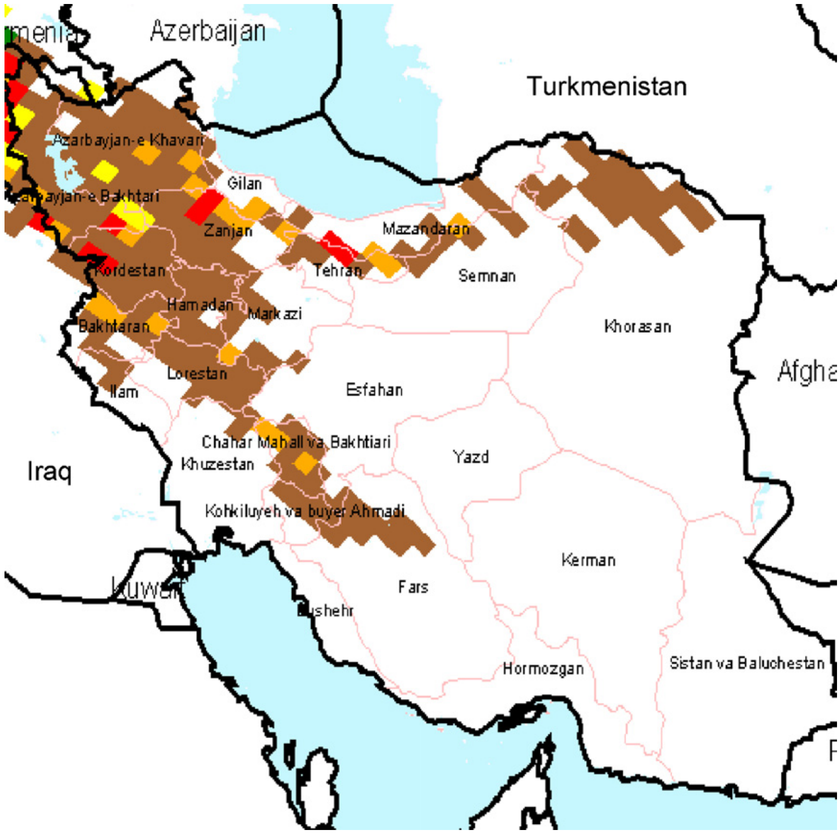


Fig. 6. Estimated wheat stage in Iran [9].

bioethanol production are obtained from FAO statistics (FAOSTAT) and agricultural ministry of Iran [7,12]. The wasted crops are available for producing ethanol.

4. Potential of bioethanol production from agricultural wastes in Iran

The potential of bioethanol production from wastes of 10 agricultural crops has been investigated. These 10 products are wheat, sugar cane, rice, barely and corn process studied. The production of potato, date, sugar beet, grape and apple process was selected as case study in Iran. Non-fossil energy sources have a high share of energy supply in Iran, while renewable energy sources have made great inroads in Iran's energy supply mix. There are many agricultural waste materials in Iran that must convert to usable materials such as biofuels.

4.1. Wheat

In Iran, most wheat (45% of total production) is used as human food. About 5% of total production is used for animal food while approximately 50% is lost as waste. Production amount of wheat is about 15 MT at present [7]. Provinces that produce high rate of wheat in Iran are Fars, Lorestan, Ilam, Khuzestan, Markazi, Hamedan, Kordestan, Zanjan, Azarbayjan, Gilan, Mazandaran Tehran, and Charmahal as given in Fig. 6. The utilization of the waste from the wheat can produce 3 GL of bioethanol per year. The annual gasoline consumption is 24 GL at present in Iran [14]. If rule imposed to use E5 (5% ethanol in gasoline as a blend fuel) as a fuel, the annual saving can reach 1.2 GL. If E10 is used the saving can reach 2.4 GL. In comparison to other conventional fuel, bioethanol can be an optimum alternative fuel. Biofuel resources are equitably distributed and less environmentally destructive than the current fossil fuel Iran. The regional potential bioethanol is shown in Table 1.

4.2. Sugar cane

Asia is the primary production region of producing sugar cane (45%), while South America is the second largest production region (35%) [7] A 4.3 MT bagasse of sugar cane is produced in Iran annually [10]. Khuzestan is the top province in Iran producing sugar cane as indicated in Fig. 7. The utilization of waste could produce 0.63 GL of bioethanol per year. The regional potential bioethanol production from sugar cane is shown in Table 2.

Table 1
Potential of bioethanol production (GL) from wheat wastes for different regions [10,11]

	Wheat wastes (Tg)	Total bioethanol (GL)
Iran	7.5	3
Asia	16	50
Africa	7	3
Europe	140	42
America	65	20
Oceania	10	4
World	382	119



Fig. 7. Estimated sugar cane stage in Iran.

4.3. Rice

Asia is the primary production region of rice with over 90% of global production and the largest harvested area for rice. In Iran, most rice (65% of total production) is used for human food. Approximately 5% of total production is used for animal food and 30% is lost as waste. A 3.5 Tg rice is produced in Iran at present [10]. Gilan, Mazandaran, Golestan, Fars and Khuzestan consequently are the top provinces in producing rice in Iran as shown in Fig. 8. A 1.05 Tg of rice waste can efficiently produce 0.378 GL of bioethanol. The regional potential bioethanol production from rice is shown in Table 3.

4.4. Barley

Europe (62%), Asia (15%) and America (14%) are the major countries in producing barley worldwide [7]. A 3 Tg barley is produced in Iran at present [10]. There are 14 provinces in Iran are producing barley as indicated in Fig. 9. A 0.6 Tg of barley waste can efficiently produce 0.21 GL of bioethanol. The regional potential bioethanol production from barley is shown in Table 4. If government imposed a rule to use E5, this can make ethanol a great replacement of gasoline.

4.5. Corn

The major production regions for corn are America (51%), Asia (26%) and Europe (12%). Regarding corn yield, the highest yield occurs in North America [7]. In Iran, most corn (65% of total production) is used for human food, 10% for animal food and about 25% is lost as waste [10]. Total production of corn is approximately 2 Tg at present, where 0.5 Tg of it is a waste [10,13]. If the cone waste is used efficiently, a 0.2 GL of bioethanol can be produced annually. It is feasible that corn wastes in Iran can be converted to bioethanol. Bioethanol can practically be used as a 5% blend with petrol in Iran's vehicles. This blend requires no engine modification and is covered by vehicle warranties (Fig. 10; Table 5).

4.6. Potato

In Iran, most potato (70% of total production) is used for human food, and 30% is lost as waste. Total production of potato is 5 Tg at

Table 2
Potential of bioethanol production (GL) from sugar cane wastes for different regions [10,11]

	Wheat wastes (Tg)	Total bioethanol (GL)
Iran	4.3	0.63
Asia	77	23
Africa	13	4
Europe	0.01	0.004
America	90	26
Oceania	7	2
World	187.01	55.004

Table 3
Potential of bioethanol production (GL) from rice wastes for different regions [10,11]

	Rice wasted (Tg)	Total bioethanol (GL)
Iran	1.05	0.378
Asia	690	202
Africa	22	7
Europe	4	2
America	40	12
Oceania	2	0.5
World	758	223.5

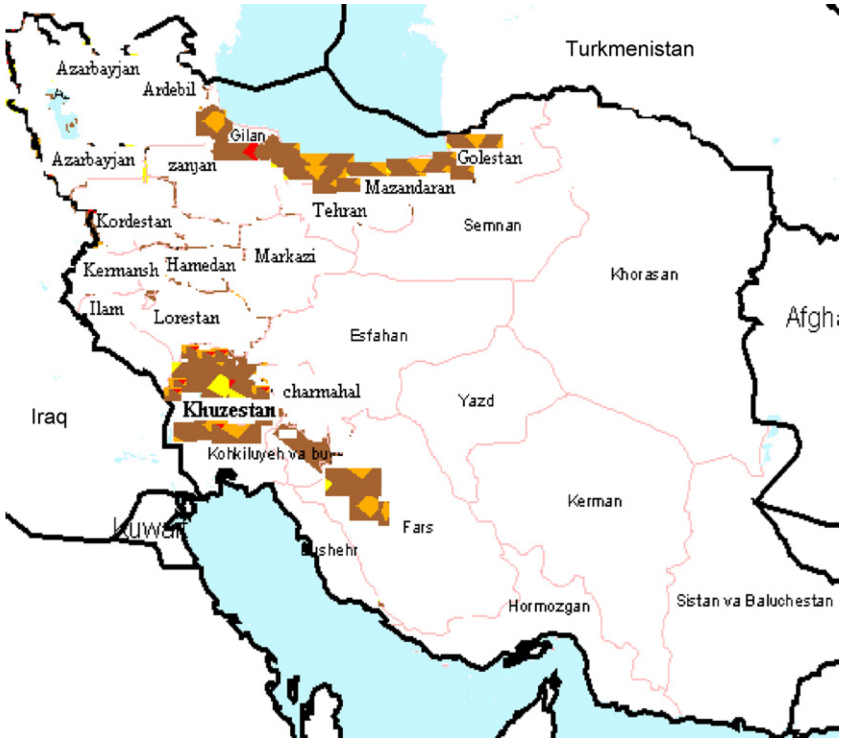


Fig. 8. Estimated rice stage in Iran.

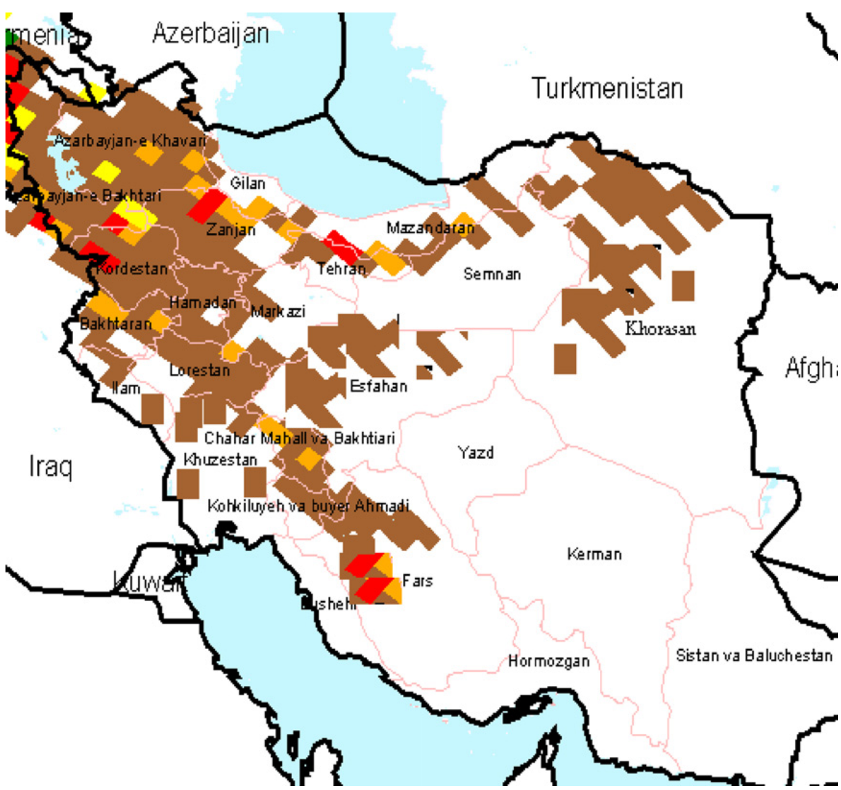


Fig. 9. Estimated barley stage in Iran.

present, where 1.5 Tg out of it is in a waste form [10]. The potato can be efficiently used to produce 0.165 GL of bioethanol per year. Fig. 11 shows the top Iranian provinces in producing potato. Biofuel resources such as bioethanol are equitably distributed and less environmentally destructive than the conventional fossil fuel.

4.7. Date

In Iran, most date (60% of total production) is used for human food, and about 40% is lost as waste. A 0.36 Tg of the total production of date which is 0.9 Tg is in a waste form [10]. If date production can be efficiently used a 0.129 GL of the date



Fig. 10. Estimated corn stage in Iran.

can be converted to bioethanol. Khuzestan, Kerman, Sistan VA Baluchestan, Bushehr and Bandar Abas Provinces are the tope provinces in Iran in producing date as shown in Fig. 12. In the future, bioethanol has the potential to provide a cost-effective and sustainable supply of energy in Iran specially production of bioethanol from agricultural wastes.

4.8. Sugar beet

A 0.25 Tg of sugar beet in Iran is wasted [10]. If the sugar beet can be efficiently utilized a 0.075 GL of bioethanol can be annually produced. Provinces that famous for producing high rate of sugar beet in Iran are Mazandaran, Khuzestan, Kerman, Esfahan, Khorasan, Fars and Zanjan respectively as indicated in Fig. 13.

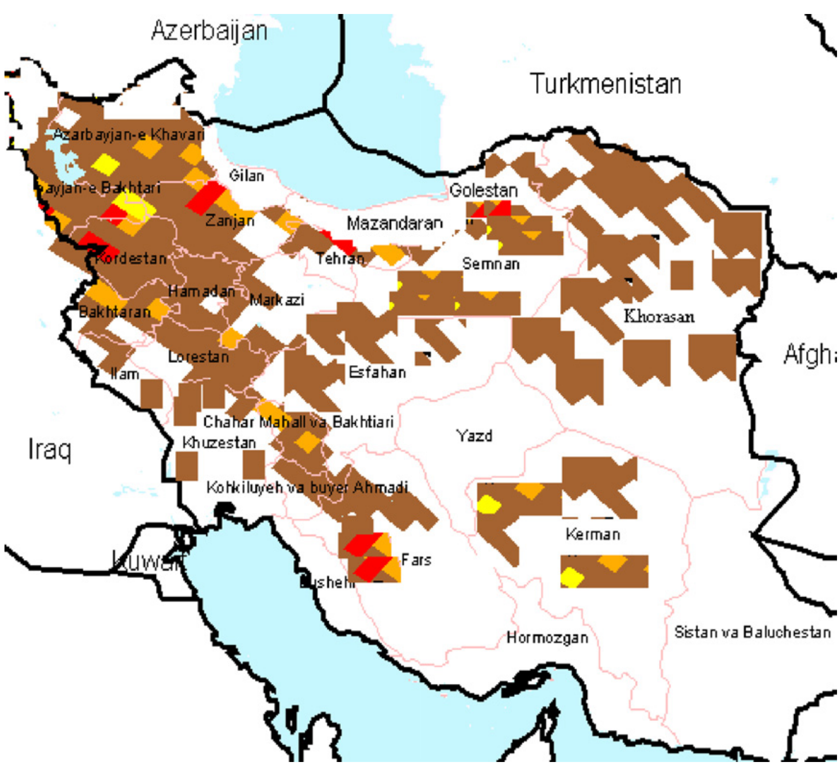


Fig. 11. Estimated potato stage in Iran.



Fig. 12. Estimated date stage in Iran.

4.9. Grape

A 0.9 Tg of grape in Iran is wasted. If this grape waste can be effectively utilized a 0.063 GL of bioethanol can be produced per year [7,10]. Provinces that famous for producing grape are respectively Khorasan, Fars, Hamedan, Zanjan, West and East Azarbaijan, Tehran, Semnan, Qazvin and Markazi as indicated in Fig. 14.

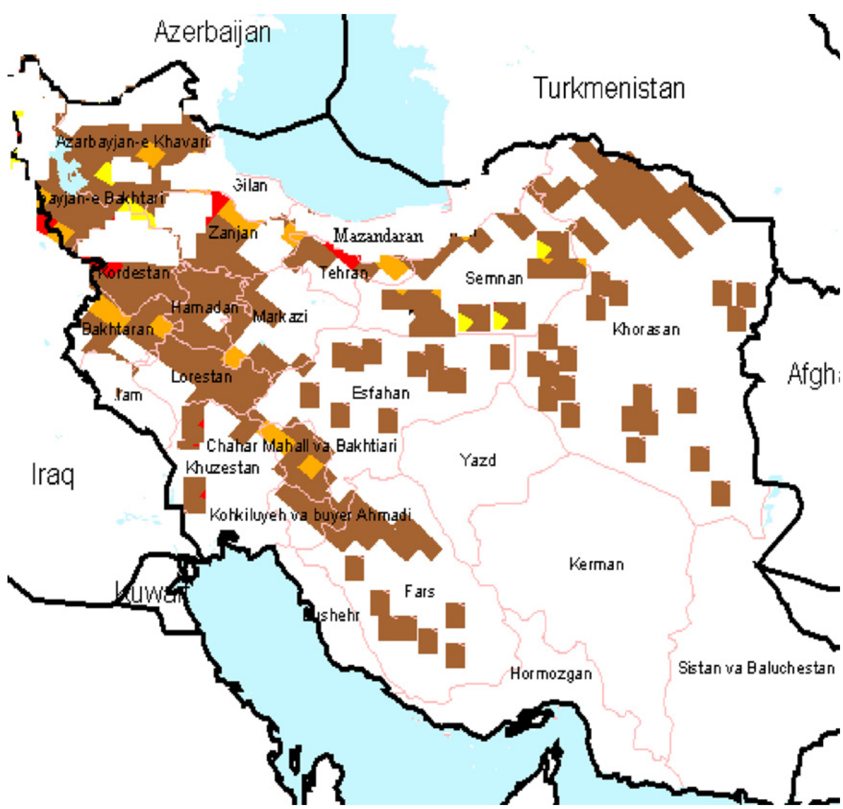


Fig. 13. Estimated sugar beet stage in Iran.



Fig. 14. Estimated grape stage in Iran.



Fig. 15. Estimated apple stage in Iran.

4.10. Apple

A 0.9 Tg of apple in Iran is wasted [10]. However if this ratio is efficiently utilized, 0585 GL of bioethanol can be produced annually. The top provinces that famous for producing apple are Azarbaijan, Khorasan, Fars, Hamedan, Tehran and Faras as indicated in Fig. 15.

5. Discussion

According to the report of the Ministry of Agricultural 2007, a 17.86 Tg of agricultural products are lost in Iran during logistic processes: handling, storage and transportation. A 50% of the total wheat production is lost as wastes which is the highest among any biofuel production source in Iran. In Iran, wheat, sugar cane, rice, barely and corn are the most contributors to the waste energy. About 4.91 GL of bioethanol can be produced from the wasted crops. Using simple technology, crop residues can ideally produce 95% of the total bioethanol production in Iran. The future bioethanol production in Iran can be an optimum alternative fuel for SI engines using E5. In Iran the wheat wastes is the major contribution for bioethanol production. If Iranian government can perfectly manage these waste materials and convert them to bioethanol, and there will be no need to import conventional fuel

Table 4
Bioethanol production (GL) from barley wastes for different regions [10,11]

	Barley wasted (Tg)	Total bioethanol (GL)
Iran	0.6	0.21
Asia	3.5	2
Africa	0.5	0.5
Europe	47	15.5
America	11	3.5
Oceania	2.5	1
World	64.5	22.5

Table 5
Bioethanol production (GL) from corn wastes for different regions [10,11]

	Barley wasted (Tg)	Total bioethanol (GL)
Iran	0.5	0.2
Asia	45	20
Africa	3.5	2.5
Europe	31	10
America	150	45
Oceania	0.5	0.1
World	230	22.5

Table 6
Potential of bioethanol production (GL) from agricultural wastes in Iran

Crop	Production (Tg)	Residual percentage (%)	Wastes (Tg)	Transfer coefficient (L/tone)	Total bioethanol (GL)
Wheat	15	50	7.5	400	3
Sugar cane (bagasse & molasses)	4 & 0.3	100	4 & 0.3	135 & 300	0.63
Rice	2	25	0.5	400	0.2
Barley	3	20	0.6	350	0.21
Corn	3.5	30	1.05	360	0.378
Potato	5	30	1.5	110	0.165
Date	0.9	40	0.36	360	0.129
Sugar beet (molasses)	0.25	100	0.25	300	0.075
Grape	3	30	0.9	70	0.063
Apple	3	30	0.9	65	0.0585
Total	39.95		17.86		4.91

to the country. This paper has recommended an ideal solution to overcome the oil crises in this country.

There is a need for more research and development on renewable energies, especially in biofuel fields. Biofuel will appear to be an attractive alternative fuel and future energy supply for Iran.

6. Conclusion

This paper showed that there is a considerable potential for utilization of agricultural residues in Iran. If the agriculture wastes efficiently utilized there will be no need to import conventional fuel to the country. The concern about the environmental pollution is growing due to the increase of the use of the fossil fuel. Producing bioethanol from the agriculture wastes can ideally replace 25% of total gasoline fuel consumption in this country. By managing this agriculture wastes, an E5 can be an optimum alternative fuel for SI engine since there is no major engine modification required to use E%. The author is strongly recommended this techniques so Iran can reduce import gasoline. Sure, there is a substantial need for more research to study other economic issue related to biofuels specially bioethanol. The potential of bioethanol production (GL) from agricultural wastes in Iran is presented in Table 6.

Acknowledgments

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